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Level 2 Chemistry, 2017

91164 Demonstrate understanding of bonding, structure, properties and energy changes

2.00 p.m. Thursday 16 November 2017
Credits: Five

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of bonding, structure, properties and energy changes.	Demonstrate in-depth understanding of bonding, structure, properties and energy changes.	Demonstrate comprehensive understanding of bonding, structure, properties and energy changes.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

A periodic table is provided on the Resource Sheet L2–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–12 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 24

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QUESTION ONE

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(a) When solid calcium chloride, $CaCl_2(s)$, reacts with water, the temperature increases.

Circle the term that best describes this reaction.

endothermic **exothermic**

Give a reason for your choice.

An exothermic reaction releases energy eg. as heat, which increases the temperature of the surroundings.

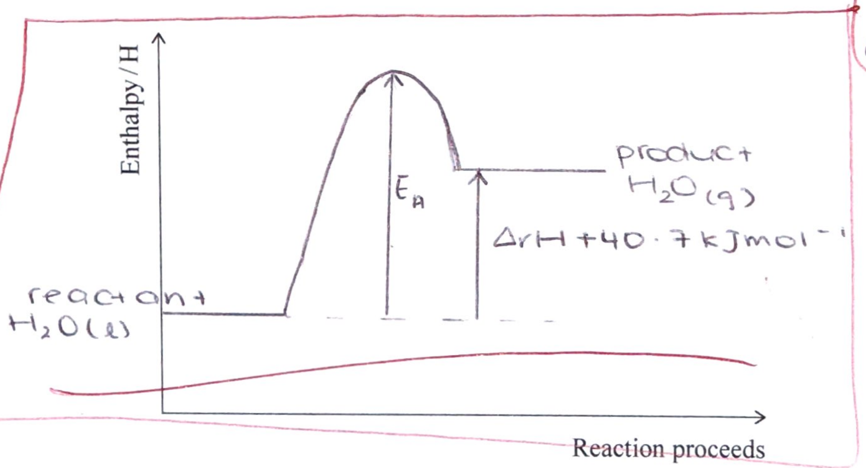
(b) When a person sweats, water is lost from the body by evaporation. This is an endothermic process. This evaporation speeds up when a person exercises.

(i) Explain why the evaporation of water in sweat from the body is endothermic, and why exercise increases this evaporation.

Sweat evaporating is $H_2O(\ell) \rightarrow H_2O(g)$. This is an endothermic reaction as energy is required (absorbed from surroundings) to break the intermolecular attractions between H_2O molecules. When a person exercises, their body will heat up, so the $H_2O(\ell)$ molecules can absorb more heat energy from their surroundings and evaporate to form $H_2O(g)$ at a greater rate.

(ii) Draw a labelled enthalpy diagram for the evaporation of water, $H_2O(\ell)$.

$H_2O(\ell) \rightarrow H_2O(g)$ $\Delta_r H^\circ = 40.7$ kJ mol^{-1}



(iii) Sodium chloride, NaCl, is another compound that is excreted from the body in sweat.

Use your knowledge of structure and bonding to explain the dissolving process of sodium chloride, NaCl, in water.

Support your answer with a labelled diagram.

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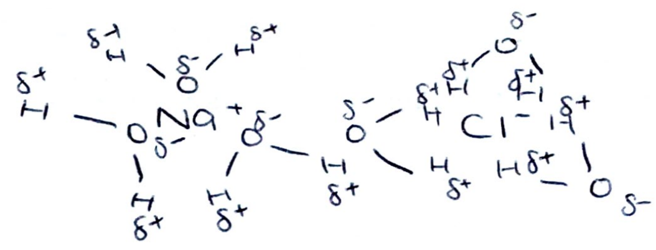
NaCl is an ionic solid with strong ionic bonds between Na^+ (cations) and Cl^- (anions). H_2O is a polar molecule with the O atom being slightly ~~po~~ negative and the H atoms being slightly positive. When NaCl is dissolved in H_2O, the positive Na^+ are attracted to the ~~δδ~~ $\delta^- O$ end of the H_2O molecule, and the negative Cl^- are attracted to the $\delta^+ H$ (slightly positive) H end of the H_2O molecule as shown in the diagram. The attractions between Na^+ and H_2O, and Cl^- and H_2O are greater than the attractions between Na^+ and Cl^-, and H_2O and H_2O. Therefore, the ionic bond between Na^+ and Cl^- is able to be broken and Na^+ and Cl^- are surrounded by H_2O molecules. Thus, NaCl is soluble and dissolves in H_2O, water (polar solvent).

Space for diagram



(c) Thermite reactions occur when a metal oxide reacts with a metal powder.

The equations for two thermite reactions are given below:

Reaction 1: $Fe_2O_3(s) + 2Al(s) \rightarrow 2Fe(s) + Al_2O_3(s)$ $\Delta_rH° = -852$ kJ mol^{-1}

Reaction 2: $3CuO(s) + 2Al(s) \rightarrow 3Cu(s) + Al_2O_3(s)$ $\Delta_rH° = -1520$ kJ mol^{-1}

Use calculations to determine which metal oxide, iron(III) oxide, $Fe_2O_3(s)$, or copper(II) oxide, $CuO(s)$, will produce more heat energy when 50.0 g of each metal oxide is reacted with aluminium powder, Al(s).

$M(Fe_2O_3) = 160$ g mol^{-1} $M(CuO) = 79.6$ g mol^{-1}

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- Reaction 1:

$n = \frac{m}{M}$ $n(Fe_2O_3) = \frac{50}{160} = 0.313$ mol

1 mol Fe_2O_3 → −852 kJ ~~mol~~

0.313 mol " " → −266 kJ ~~mol~~ (3sf)

- Reaction 2:

$n = \frac{m}{M}$ $n(CuO) = \frac{50}{79.6} = 0.628$ mol.

3 mol CuO → −1520 kJ ~~mol~~

1 mol " " → −507 kJ ~~mol~~

0.628 mol " " → −318 kJ ~~mol~~

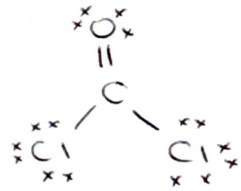
Therefore, $CuO_{(s)}$ will produce (52 kJ) more heat energy when 50g of CuO is reacted with Al(s), as shown in reaction 2.

ood

E8

QUESTION TWO

(a) (i) Draw the Lewis structure (electron dot diagram) for the following molecules, and name their shapes.

Molecule	1 6 7 14 HOCl	4 6 14 $COCl_2$ 24	5 21 NF_3 26
Lewis structure			
Name of shape	bent	trigonal planar	trigonal pyramid.
Approximate bond angle around the central atom	109.5°	120°	109.5°

(ii) Justify the shapes and bond angles of HOCl and $COCl_2$.

• HOCl has 4 regions of electron density around its central atom O. Since electrons repel and are maximum distance apart, HOCl has a bond angle of 109.5° (based on tetrahedral shape) around the central atom O. HOCl has 2 bonded and 2 non-bonded regions of electron density around central atom O, therefore has a bent shape as only the bonded regions are visible (bonded to H and Cl).

• $COCl_2$ has only 3 regions of electron density around its central atom C. Since electrons repel and are maximum distance apart, the bond angle around the central atom C is 120°. Since all 3 regions of electron density around central atom C are bonded, the shape of $COCl_2$ is trigonal planar.

(b) Three-dimensional diagrams for two molecules are shown below.

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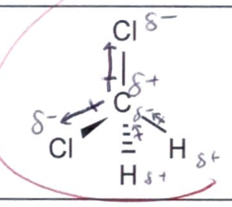
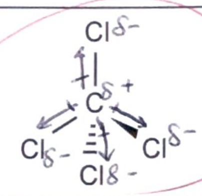
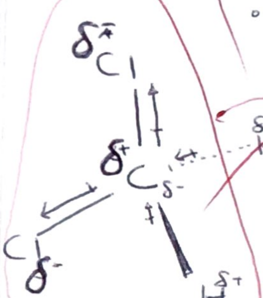
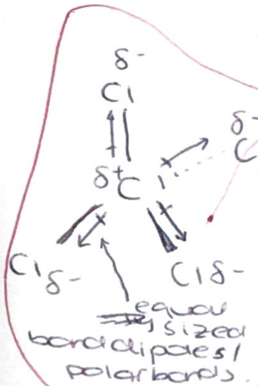
Molecule		
Name	Dichloromethane	Tetrachloromethane
Polarity of molecule	polar	non-polar

(i) In the boxes above, identify the polarity of each molecule, by writing either **polar** or **non-polar.**

(ii) Justify your choices.



• Dichloromethane has 2 bond dipoles from C to Cl and 2 (smaller) bond dipoles from H to C. There are bond dipoles between C and Cl as there is a difference in electronegativity (attracting pull of an atom on a bonded pair of electrons) → Cl is more electronegative than C, so the electrons are closer to the Cl atom. There are also 2 smaller bond dipoles between C and H due to the difference in electronegativity (C is more electronegative than H). Since the 4 bond dipoles around central atom C are unequally sized (asymmetrical), the bond dipoles do not cancel and thus dichloromethane is polar. ~~(there is a molecula~~r dipole) • Tetrachloromethane ~~also~~ has 4 equally sized bond dipoles (/polar bonds) from C to Cl as Cl is more electronegative than C (ele~~ctronegativity difference = bond~~ dipole). Since these 4 bonds are arranged in a tetrahedral shape and are equally sized (symmetrical) the bond dipoles/polar bonds cancel out and tetrachloromethane is non-polar.



(c) Hydrazine, N_2H_4, is used as rocket fuel.

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Use calculations to determine which of **Reaction 1** or **Reaction 2** releases more energy.

Reaction 1: $N_2H_4(g) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$

Reaction 2: $N_2H_4(g) + 2F_2(g) \rightarrow N_2(g) + 4HF(g)$

The structure of each chemical species is shown in the box below.

hydrazine	oxygen	fluorine	nitrogen	water	hydrogen fluoride
$H_2N{-}NH_2$ (H, H / N–N / H, H)	O=O	F–F	N≡N	H–O–H	H–F

Use the average bond enthalpies given in the table below.

Bond	Average Bond enthalpy /kJ mol^{-1}	Bond	Average Bond enthalpy /kJ mol^{-1}
H–H	436	N–N	158
H–F	567	F–F	159
N–H	391	O=O	498
O–H	463	N≡N	945

Show your working and include appropriate units in your answer.

• Reaction 1:

Bond breaking			Bond making	
4 ×	N–H	4×391	N≡N	945
	N–N	158	2×2×O–H	4×463
	O=O	498		2797.
		2220		

2220 ↑ ΔH ↓ −2797

ΔrH = bonds broken − bonds made

ΔrH = 2220 − 2797 = −577 kJ mol^{-1}

6o ✓

• Reaction 2:

Bond breaking		Bond making	
4×N–H	4×391	N≡N	945
~~2×~~ N–N	158	4×H–F	4×567
2 × F–F	2×159		3213.
	2040		

2040 ↑ ΔrH ↓ −3213

ΔrH = bonds broken − bonds made

= 2040 − 3213

= −1173 kJ mol^{-1}

Therefore reaction 2 releases more energy (kJ mol^{-1}) (per mol.)

E8

QUESTION THREE

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(a) Complete the table below by stating the type of solid, the type of particle, and the type of bonding (attractive forces) between the particles in each solid.

Solid	Type of solid	Type of particle	Attractive forces between particles
Al(*s*) (aluminium)	metallic lattice	cations + electrons	metallic bonds.
MgCl$_2$(*s*) (magnesium chloride)	ionic lattice	cations + anions	ionic bonds
S$_8$(*s*) (sulfur)	molecular solid	molecules	(weak) intermolecular forces

(b) Circle the substance which has the lowest melting point.

Al(*s*) MgCl$_2$(s) S$_8$(s)

Justify your choice, referring to the attractive forces between the particles of ALL three substances.

· Al(s) is a metallic lattice with strong non-directional metallic bonding between (Al^{3+}) cations and a sea of delocalized electrons. $MgCl_{2(s)}$ is an ionic lattice with strong ionic bonds between (Mg^{2+}) cations and (Cl^-) anions. $S_{8(s)}$ is a molecule with weak intermolecular attractions to other S_8 molecules. Out of all 3 substances, S_8 has the weakest attractive forces between particles: weak intermolecular / van der Waals forces. This means these attractions require the least energy to break compared to metallic bonds and ionic bonds. Therefore, S_8 has the lowest melting point as it requires the least (heat) energy / temperature (average measure of kinetic energy of particles) to weaken / break the attractive forces (weak intermolecular ~~attractions~~

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attractions) between particles (molecules).

Question Three continues on the following page.

(c) Circle the substance which is malleable.

Al(s) $MgCl_2(s)$ $S_8(s)$

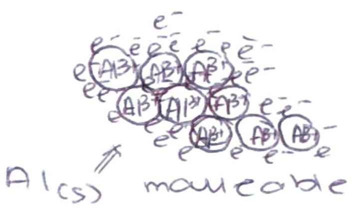
Justify your choice by referring to the structure and bonding of your chosen substance.

You may include a diagram or diagrams in your answer.

Al(s) is a metallic lattice with strong non-directional metallic bonding between the lattice of cations (Al^{3+}) and the sea of delocalized electrons. Due to this strong non-directional metallic bonding, Al(s) is malleable. When the metallic lattice is struck/hit, the layers of cations are able to slide past one another without disrupting the metallic bonds as the sea of delocalized electrons can freely move and maintain strong (non-directional) metallic bonds.

(However, $MgCl_2$ and S_8 are not malleable as their ionic bonds and weak intermolecular forces are easily broken when struck/hit as described in diagram below).

Space for diagram



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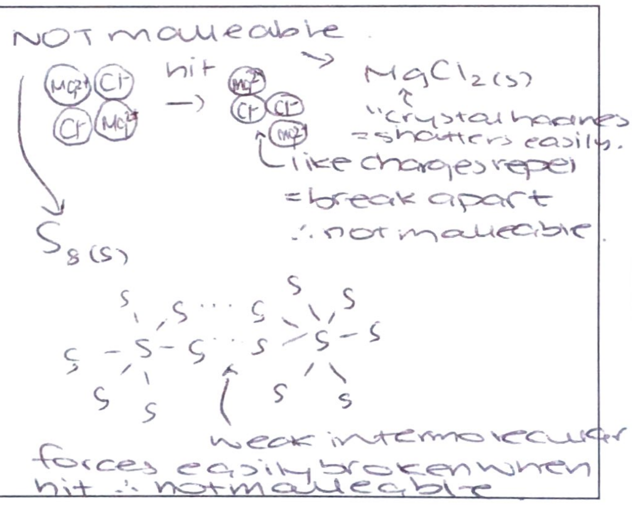

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Extra paper if required.
Write the question number(s) if applicable.

QUESTION NUMBER

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Extra paper if required.
Write the question number(s) if applicable.

QUESTION NUMBER

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Subject:	Chemistry	Standard:	91164	Total score:	24

Q	Grade score	Annotation
1	E8	This candidate received a grade score of E8 as the response comprehensively relates increased heat from exercise to increased bond breaking during evaporation, evaluates the attractions of H_2O and NaCl with words and diagrams, as well as analysing and correctly contrasting the energy given out during thermochemical reactions.
2	E8	This candidate received a grade score of E8 as the response elaborates fully on the factors that determine shape and polarity of molecules while also correctly evaluating the relative enthalpy changes of hydrazine reactions.
3	E8	This candidate received a grade score of E8 as the response comprehensively relates bonding strength with melting points while also elaborating on the factors that enable the malleability of aluminium to occur.